European Research Studies
Volume VI, Issue (1-2), 2003

The Characteristics Of R&D Performers

Theodore A. Papadogonas[*]

Abstract

This paper investigates the main factors that determine R&D at the firm level, using data from Greek Manufacturing for 1996-1999. The approach adopted combines the recommendations of the industrial organization and the resource-based view of the firm lines of analysis. Results indicate that R&D is positively influenced by firm size, technological environment, human capital, physical capital and government support. It is also shown that firms which are engaged in R&D activities improve their performance faster than the average firms that belong to the same industries.

Keywords*: Firm level, Process R&D, Product R&D*

JEL Classification*: O31*

1. Introduction

Despite the great importance of technology as one of the crucial factors that affect the rates of economic development, the economic (and not only) competition of nations, enterprises etc., it is only the last 40 – 50 years when it became subject of research in economics. As a possible explanation we could mention the predominance of the neoclassical theory, which presents a static picture of economic reality, where the technological background is treated as exogenous and is not attempted to be explained. Some important exceptions were those of J. Schumpeter (1942), K. J. Arrow (1962) and J. Schmookler (1966).

According to Schumpeter, the individual entrepreneur, which played a crucial role for the invention and implementation of new technologies at the first stage of economic development, has been replaced by the large enterprise, which tends to institutionalise – organise the inventive process. This is so because of three distinct reasons. First, only a large firm could bear the cost of R&D programmes as well as the cost of routinisation of the entire inventive process. Second, a large and diversified firm could absorb failures by innovating in a wide front. Third, it needs some element of market “control” to reap the rewards of innovation. Thus, the most

[*] Theodore A. Papadogonas, Department of Accounting and Finance Athens University of Economics and Business Please address all correspondence to: Theodore Papadogonas 10, Kivelis Street, Athens 111 46 Greece, E-mail address: tpap@gsrt.gr

proper environment for R&D is that of large and oligopolistic firms, where the risk, that is inherent in every technological invention, can be reduced due to increased appropriability of the returns.

In most of the empirical literature that followed, the Schumpeterian views have been interpreted and tested as continuous relationships between firm size, industry concentration and innovative activity[1]. During the first three decades after the end of Second World War, the so-called Schumpeterian hypotheses became accepted. Typical studies which tested these hypotheses, estimated cross-sectional regressions of R&D or R&D intensity (in terms of employment or sales) on firm size and/or industry concentration, concluding that R&D increases more than proportionately with firm size and is influenced positively by market concentration. Recently these results have been criticized that they did not control for other firm and industry characteristics. The more comprehensive specifications that have been used in the last two decades have indeed shown that the early results are not reliable. Today the consensus of the tests of the Schumpeterian hypotheses (see Cohen and Levin, 1989; Cohen , 1995; Symeonidis, 1996) is that:

a) R&D increases monotonically, and proportionately above a certain firm size, with firm size and
b) there is no strong indication of a significant positive effect of industrial concentration on R&D.

Until recently, the dominant theoretical approach for analysing the determinants of R&D has been the industrial organization framework, which emphasizes industry characteristics such as concentration, industry size and growth, technological opportunity and appropriability conditions. This approach stresses that the most crucial factors which determine R&D activity lie in environmental conditions which are exogenous to the firm. This can be thought of as a structural, black-box approach, which regards firms belonging to the same industry as largely homogeneous and thus ignores the idiosyncratic, specific features of individual firms.

According to a more recent line of thought, the resource – based approach[2], firm – level resources and capabilities are assumed as more fundamental for explaining differences in R&D among firms. Firms are assumed to follow heterogeneous historical development paths and, as a result, they generate different skills and competences, which are expected to affect R&D activities more than the external – structural characteristics.

In this paper we will try to combine these two views and shed some light as to which factors retain their significance in explaining R&D intensity when taking into account both these theoretical approaches.

---

[1] Although in the early years innovative activity has been proxied almost exclusively by R&D expenditures or personnel, as time went by new data became available such as patents, innovation counts, sales of innovative products and/or combinations of these. The results differ depending on which exactly measure is adopted. Since, due to data limitations, in this paper we confine ourselves to R&D expenditures, all the subsequent discussion is based on comparable results from other studies.

[2] See for example Wernerfelt (1984), Prahalad and Hamel (1990), Peteraf (1993) and for an application on R&D activities Del Canto and González (1999).

2. The Data

The firm level data which are used in this study come from two sources: data on firm level R&D and other related characteristics are obtained through the Greek R&D survey (which is considered a census) for year 1996. This database was combined with the ICAP directory which collects balance sheet data for all SA and Ltd companies in Greece. The combination of these two sources gave a number of 4518 manufacturing firms for 1996 (classified by 4-digit NACE Rev. 1 industries) out of which 211 reported R&D expenditures for the same year[3].

R&D data refer to both formal and informal R&D expenditures. Sixty seven firms perform all of their R&D outside a formal R&D department and for the rest (134) firms 23.4% of R&D expenditures is also performed outside their R&D department.

3. The Empirical Model

As noted earlier, in this paper effort is made to incorporate as determinants of R&D intensity all important variables that have been used both in the Industrial Organization literature and the more recent resource – based view of the firm (which shares some common features with evolutionary theories).

The dependent variable in our model is R&D intensity (R&D expenditures to sales) which in some specifications is split into product R&D and process R&D in order to bring to light the forces that lie behind different aspects of R&D activity. The expected influence of the explanatory variables on R&D intensity is as follows:

Firm size

This is the most widely used variable suggested by the Schumpeterian theory. In addition, J. K. Galbraith (1985) argued that current innovative activity requires vast sums of money for technical personnel, engineers, scientists, and their equipment. The needed resources are available only to large firms. Thus, firm size is expected to have a positive effect on R&D intensity.

Market concentration

A concentrated market is assumed to favour R&D activities since it reduces the uncertainty associated with R&D and facilitates the appropriability of the returns of innovation. Schumpeter argued also that the incentive to engage in innovative activity is associated to the expectation of some degree of ex post market power.

Market demand and market growth

The role of demand in determining R&D activity was emphasized by Schmookler (1966) and the questions as to which is the most important factor for technological change (“demand – pull” or “technology – push”) has not yet been

[3] The Greek R&D survey is conducted biannually, based on a special questionnaire which is designed following the guidelines of OECD and Eurostat (Frascati manual). The small percentage of R&D performers is not surprising if we consider the low level of total R&D expenditures in Greece (1996: 0.5% of GDP) and furthermore the small contribution of the business enterprise sector to total R&D spending (Business Enterprise Expenditure on R&D -BERD- accounts only for 25% of Gross Expenditure on R&D -GERD).

answered satisfactorily. Furthermore, a rapidly growing market is expected to increase the incentive for innovativeness and especially for product innovation.

Government subsidization of R&D

The "public good" characteristics of technology imply that the social rate of return of R&D is greater than the private one and this has led most governments to support business enterprise R&D with a variety of policy measures. Although the empirical examination of the complementarity or substitutability effect of government subsidies on privately – financed R&D has yielded rather mixed results (David et al., 2000), it is anticipated that a relatively high share of government funds in a firm's total R&D spending indicates a greater number of research opportunities.

Technological opportunity

Apart from the share of R&D financed by government, there exist other technological opportunities that should be taken into account, in order to avoid biased inferences. Technological opportunity is the rate at which more or less exogenous and cumulative advances in science and technology generate new innovative possibilities. Scherer and Ross, (1990), Pavitt (1984), and Nelson (1986) point out that innovation in the so-called "high-tech" industries depends on R&D activities which are science based and take often place in organically independent science laboratories. Thus, the increasing role of scientific inputs in the innovative process can be taken as evidence of the importance of factors exogenous to competitive processes among private economically motivated actors.

I included three such dummies according to the OECD classification (OECD, 2001), mainly as control variables since the major reason for incorporating them is to condition the performance of the other variables (there is no ambiguity about their importance in the literature).

Capital intensity

It is hypothesized that in order to carry out R&D activities a firm should first invest significantly in technical equipment. Thus, large capital intensity should favour R&D expenditures.

Human capital

A special form of capital is human capital. Highly qualified personnel (in terms of experience, skills, know-how etc.) greatly facilitates the generation of both product and process innovations, which in turn presupposes investments in R&D.

Export intensity

The degree to which a firm is exposed to international trade is assumed to increase its' tendency to engage in R&D activities, either through a larger market size (which increases the returns on R&D) or through the need to adapt to the more demanding international standards.

Financial autonomy

Since firms may be unwilling or unable to borrow substantial funds (due to imperfections in capital markets), internally generated funds are necessary for sizable R&D effort. To test these conjectures we have included in the analysis a measure of leverage and a measure of non-distributed profits.

Age

It has been argued (Jovanovich, 1982) that young firms are confronted with grater uncertainty and this could result in less R&D effort. On the other hand, the continuing recession of Greek manufacturing since the late 1970's has led many established firms to close down due to excess debt, creating an advantage for younger firms. Thus, the sign of the age variable should be considered as indeterminate.

Following the previous discussion the equation to be estimated is:

RDI = f (lnSales, Herf, lnIndSales, IndGrowth, GovRD, D_H, D_{MH}, D_{ML}, Amortisation, SPersonnel, XI, NDP, Leverage, Age) (1)

Where:

RDI: the ratio of R&D expenditures to firms sales, 1996.

LnSales[4]: the natural logarithm of firm sales, 1996.

Herf: 4-digit industry Herfindahl index of concentration, 1996.

LnIndSales: the natural logarithm of 4-digit industry sales, 1996.

GovRD: the share of R&D financed by the government.

D_H, D_{MH}, D_{ML}: technology dummies differentiating high, medium-high and medium-low tech industries. The low tech industries form the omitted group.

Amortisation (proxy for capital intensity): the ratio of depreciation to sales, 1996.

SPersonnel (proxy for human capital): the ratio of the number of employees having an academic degree to the total number of employees, 1996.

XI: the ratio of firm's exports to sales, 1995[5].

NDP: the ratio of non-distributed profits to sales, 1995[5].

Leverage: the ratio of long- and short-term liabilities to equity, 1996.

Age: the age of firm in number of years.

4. Who does R&D?

Before I proceed to the estimation results we will firstly present some interesting comparisons between R&D and non-R&D performing firms for 1996. The procedure is as follows: First, for each one of the variables shown below (Tables 1, 2, 3) the R&D performers were removed from their 4-digit industry population. Then the average value of these variables for non-R&D performers was calculated. Finally, a t-test was conducted comparing R&D performers with average non-R&D performers in each industry. The results are given in Tables 1-3:

---

[4] I also experimented with other measures of firm size, such as assets and employment. The regression results do not change significantly and thus are not reported.

[5] In order to avoid simultaneity problems the export intensity and the non-distributed profits intensity variables appear in the regression analysis with a one-year lag.

Table 1: Comparisons (1996) between R&D and non-R&D performers with respect to firm size*

	Assets	**Sales**	**Employment**
R&D performer > Average non-R&D performer	130	124	129
R&D performer < Average non-R&D performer	13	15	20
Insignificant difference	68	72	62
Total	211	211	211

* t-tests: level of significance is 5%

Table 2: Comparisons (1996) between R&D and non-R&D performers with respect to profits*

	Net Profits/Sales	**Non-distributed Profits/Sales**
R&D performer > Average non-R&D performer	64	90
R&D performer < Average non-R&D performer	36	50
Insignificant difference	111	71
Total	**211**	**211**

* t-tests: level of significance is 5%

Table 3: Comparisons (1996) between R&D and non-R&D performers with respect to leverage and amortisation*

	Leverage	**Amortisation**
R&D performer > Average non-R&D performer	43	71
R&D performer < Average non-R&D performer	69	51
Insignificant difference	99	89
Total	**211**	**211**

* t-tests: level of significance is 5%

Despite of (or thanks to) the simplicity of these tests, some interesting conclusions emerge:

- R&D performers are larger than the average non-R&D performing firm of the same industry (Table 1). This result is extremely robust, since it is based on three different measures of firm size. It also means that R&D performers have larger market shares than the average firm and thus can be seen as a confirmation of Schumpeter's conjectures.
- R&D performers are also more profitable than non-R&D performers and they also retain a higher proportion of their profits, a strategy which, as stated earlier, can facilitate in the future the carrying out of R&D activities (Table 2).

• R&D performers have lower levels of debt (as shown by the leverage variable) than non-R&D performers. They also are more capital-intensive than the latter (Table 3).

In short it can be inferred that firms that are engaged in R&D activities perform better than their industry average firm for all of the variables tested. The differences are more striking with respect to the firm size variable.

5. The determinants of R&D intensity

After these simple comparisons, we come now to the core of the paper by presenting estimation results for equation (1) specified above. This equation is estimated[6] for the full sample of 211 R&D performing firms and for two sets which depend on firm size and technological opportunity. The results are given in Table 4:

Table 4. Determinants of R&D Intensity

	All Firms (n=211) (a)	Firms in High and Medium-high technology industries (n=77) (b)	Firms in Medium-low and low technology industries (n=134) (c)	Small Firms with low (n=71) (d)	Medium Firms (n = 70) (e)	Large Firms (n = 70) (f)
lnSales	-0.012***	-0.020	-0.012***	-0.038	-0.001	-0.002
	(3.167)	(1.642)	(2.956)	(1.270)	(0.192)	(0.072)
Herf	-0.006	0.007	0.009	-0.109	0.017	0.001
	(0.274)	(0.186)	(0.552)	(1.136)	(1.354)	(0.128)
lnIndSales	-0.002	0.001	0.005	-0.001	0.001	-0.001
	(0.405)	(0.006)	(1.230)	(0.079)	(0.216)	(0.037)
IndGrowth	-0.017	-0.044	0.027	-0.072	0.016	-0.003
	(0.880)	(1.281)	(1.291)	(0.805)	(0.793)	(0.379)
GovRD	0.018**	0.042	0.014**	0.043*	-0.003	-0.008***
	(2.159)	(1.355)	(2.090)	(1.926)	(0.607)	(2.981)
Amortisation	0.191***	0.405**	-0.041	0.218	-0.063	0.146
	(2.868)	(2.609)	(0.743)	(1.317)	(1.284)	(1.595)
SPersonnel	0.103***	0.165**	0.054**	0.165*	0.061***	0.003
	(2.780)	(2.214)	(2.392)	(1.970)	(3.440)	(0.486)

[6] In these estimations we restrict the analysis only to R&D performing firms.

XI	0.007	0.066	-0.008	0.018	0.008	0.002
	(0.446)	(0.954)	(1.208)	(0.309)	(1.132)	(0.508)
NDP	0.002	-0.010	0.002*	-0.002	0.018	-0.004
	(1.172)	(0.324)	(1.875)	(0.661)	(1.463)	(0.676)
Leverage	-0.001	0.011	0.001	-0.001	-0.004	-0.001
	(1.006)	(0.620)	(1.401)	(0.114)	(1.180)	(0.994)
Age	-0.001	-0.001*	0.001	-0.001	-0.002**	-0.007
	(0.653)	(1.983)	(0.783)	(0.645)	(2.064)	(0.130)
Adj.R-squared	0.250	0.241	0.254	0.219	0.257	0.265

* Significant at the 10% level (two-tailed test), ** Significant at the 5% level (two-tailed test), *** Significant at the 1% level (two-tailed test).
t ratios are in parentheses. Standard errors are White heteroskedasticity nsistent.

The results of Table 4 could be interpreted as follows:

First, the size variable is significant only in the overall sample and the medium-low technology subsample, but, contrary to the a priori expectations, its sign is negative. However, the more dependable (with regard to size) equations (b), (c) and (d) of Table 4 indicate that there is no relationship between firm size and R&D intensity, as Klette and Kortum (2002) have also stated in their stylised facts concerning the empirical evidence on patterns of R&D investment.

Second, the robustly significant variables are only the proxies for human capital (SPersonnel), physical capital (Amortisation) and R&D subsidies (GovRD). All coefficients of these variables show the expected signs with the remarkable exception of the R&D subsidies variable for the large firms subsample. It seems that for large firms government subsidization is not effective as a measure for increasing R&D intensity.

Third, all other variables used fail to achieve significance. Concerning especially the concentration and demand variables it should be noted that it is the inclusion of technology dummies and firm-specific variables (such as human and physical capital) that renders them insignificant[7]. These resullts are not surprising, since, as Cohen (1995) in his excellent survey of empirical studies of innovative activity concludes "… empirical findings leave little support for the view that industrial concentration is an independent, significant, and important determinant of innovative behavior and performance …" (p. 196) and, with regard to demand, "… there are no notably robust findings" (p. 214).

In order to identify the effects of the above used variables on different segments of R&D, we run the same regressions but using as dependent variable alternatively

[7] This result was checked in various unreported regressions using alternatively the Herfindahl index and the 4-firm concentration ratio. Only in those specifications with no technology dummies or firm-specific variables, had concentration and demand significant coefficients.

Process R&D intensity and Product R&D intensity. The Tobit estimation results are given in Tables 5 and 6:

Table 5. Determinants of Process R&D Intensity (Tobit estimation)

	All Firms (n=211) (a)	Firms in technology (b)	Firms in technology (c)	Small (n=71) (d)	Medium (n = 70) (e)	Large (n = 70) (f)
lnSales	-0.002	-0.002	-0.002	-0.004	0.002	-0.001
	(1.425)	(1.351)	(1.241)	(0.738)	(0.389)	(0.552)
Herf	0.004	0.016*	-0.001	-0.021	0.018	0.004
	(0.590)	(1.889)	(0.146)	(0.943)	(1.361)	(1.455)
lnIndSales	-0.001	0.002	0.001	-0.001	0.002	0.001
	(0.285)	(0.149)	(0.556)	(0.335)	(0.722)	(0.507)
IndGrowth	0.001	-0.014	0.039***	-0.019	0.033*	-0.002
	(0.054)	(1.534)	(2.992)	(1.039)	(1.882)	(0.536)
GovRD	0.008***	0.009**	0.008**	0.023***	0.005	-0.003*
	(2.736)	(1.983)	(2.055)	(3.151)	(1.030)	(2.228)
Amortisation	0.007*	0.006	0.008	0.003	-0.019	-0.006
	(1.923)	(1.321)	(1.603)	(0.520)	(0.342)	(0.266)
SPersonnel	0.009	0.020**	0.004	0.005	0.029**	-0.001
	(1.351)	(2.447)	(0.441)	(0.328)	(2.092)	(0.552)
XI	-0.002	0.012	-0.007	-0.005	0.004	0.001
	(0.404)	(1.508)	(1.228)	(0.409)	(0.511)	(0.663)
NDP	0.001	-0.001	-0.008	-0.001	0.023	-0.004
	(0.071)	(0.012)	(0.040)	(0.428)	(1.407)	(1.437)
Leverage	0.002	0.001	0.003	-0.001	-0.008**	0.006
	(0.161)	(0.694)	(0.245)	(0.268)	(2.812)	(0.192)
Age	-0.002	-0.001*	0.008	0.006	-0.005	-0.008
	(0.300)	(1.834)	(1.019)	(0.322)	(0.433)	(0.384)
Log	404.7	143.0	270.9	107.2	129.8	255.9

* Significant at the 10% level (two-tailed test), ** Significant at the 5% level (two-
t ratios are in parentheses.

Table 6. Determinants of Product R&D Intensity (Tobit estimations)

	All Firms (n=211)	Firms in technology	Firms in technology	Small (n=71)	Medium (n = 70)	Large (n = 70)

	(a)	(b)	(c)	(d)	(e)	(f)
lnSales	-0.008**	-0.013	-0.009***	-0.026	0.002	-0.001
	(2.563)	(1.391)	(3.182)	(1.209)	(0.397)	(0.353)
Herf	-0.005	-0.007	0.138	-0.052	-0.002	0.004
	(0.266)	(0.154	(0.814)	(0.598)	(0.183)	(0.543)
lnIndSales	-0.002	-0.004	0.006**	-0.002	-0.002	0.001
	(0.425)	(0.421)	(1.978)	(0.132)	(0.913)	(0.600)
IndGrowth	0.003	-0.027	0.032	-0.025	0.012	-0.007
	(0.156)	(0.573)	(1.415)	(0.366)	(0.798)	(0.862)
GovRD	0.007	0.036	0.004	0.029	-0.005	-0.005*
	(0.956)	(1.412)	(0.554)	(0.941)	(1.213)	(1.700)
Amortisation	0.026***	0.431**	0.018**	0.293	0.020	0.149***
	(2.821)	(2.561)	(2.084)	(1.606)	(0.428)	(3.004)
SPersonnel	0.083**	0.152***	0.034**	0.154***	0.038***	0.004
	(2.452)	(3.513)	(2.246)	(2.622)	(3.264)	(0.619)
XI	-0.004	0.055	-0.014	0.023	-0.004	-0.002
	(0.307)	(1.225)	(1.470)	(0.439)	(0.583)	(0.445)
NDP	0.001	-0.010	0.001	-0.003	0.023*	0.001
	(0.525)	(0.178)	(0.300)	(0.240)	(1.758)	(0.231)
Leverage	-0.001	0.011	-0.001	0.001	-0.002	-0.005
	(1.062)	(0.950)	(0.059)	(0.155)	(0.088)	(0.725)
Age	-0.001	-0.001	0.001	-0.001	-0.003	-0.002
	(0.736)	(1.116)	(1.470)	(0.896)	(0.316	(0.470)
Log	231.4	72.4	217.5	49.6	169.5	196.9

* Significant at the 10% level (two-tailed test), ** Significant at the 5% level (two-
t ratios are in parentheses.

It is evident that the regressors follow basically the same patterns, the main difference being the insignificance of the R&D subsidies in <u>all</u> equations of Table 6 (with Product R&D intensity as the dependent variable). This leads to an important policy conclusion. Governments should concentrate their support in firms which focus mainly on Process R&D in order to achieve significant results. The explanation should be the long-term nature of Process R&D in relation to Product R&D.

6. Some indications on the benefits from R&D

We come now to re-compare 1996 R&D performers with their industries' average firms, three years later. The ICAP directory for 1999 contains financial data for 4838 manufacturing firms. From the 211 (1996) R&D performers 13 firms were not possible to identify in this 1999 register. For the remaining 198 firms Tables 7 –

9 present the comparisons with the corresponding industries' average firms both for 1996 and 1999, following the same procedure of section 4 above.

Table 7: Comparisons (1996, 1999) between R&D and non-R&D performers with respect to firm size*

	Sales 1996	Sales 1999	Employment 1996	Employment 1999
R&D performer > Average non-R&D performer	115	120	121	131
R&D performer < Average non-R&D performer	13	14	18	15
Insignificant difference	70	64	59	52
Total	**198**	**198**	**198**	**198**

* t-tests: level of significance is 5%

Table 8: Comparisons (1996, 1999) between R&D and non-R&D performers with respect to profits*

	Profits/Sales 1996	Profits/Sales 1999	Non-distributed Profits/Sales 1996	Non-distributed Profits/Sales 1999
R&D performer > Average non-R&D performer	61	85	83	89
R&D performer < Average non-R&D performer	35	36	49	47
Insignificant difference	102	77	66	62
Total	**198**	**198**	**198**	**198**

* t-tests: level of significance is 5%

Table 9: Comparisons (1996, 1999) between R&D and non-R&D performers with respect to leverage and amortisation*

	Leverage 1996	Leverage 1999	Amortisation 1996	Amortisation 1999
R&D performer > Average non-R&D performer	41	27	69	96
R&D performer < Average non-R&D performer	61	63	48	34
Insignificant difference	96	108	81	68
Total	**198**	**198**	**198**	**198**

* t-tests: level of significance is 5%

R&D performers not only were larger than non R&D performers (1996), but they did also grow faster. This is more evident from the comparisons based on employment, meaning that R&D performers create more employment than non R&D performers. This is an important finding, especially in high-unemployment periods such as the current one for Greece.

In all aspects examined in Tables 7 – 9 the comparisons are in favour of R&D performers (despite their better initial positions). The more striking improvements concern Profitability and Amortisation.

7. Conclusions

This paper has attempted to investigate a number of possible factors determining R&D in manufacturing industries at the firm level. This was done through two procedures: by comparing R&D with non-R&D performers and by regression analyses for samples among R&D performers.

We summarise our most robust results: First, R&D performers are larger, more profitable, more capital intensive and less indebted than non-R&D performers in most industries. They also tend to increase their distance from the latter as time goes by. Second, among R&D performers the main factors determining R&D intensity is technological opportunity, human and physical capital. Third, the government support for R&D seems to be effective only for small and medium-sized firms and for the part of R&D that is directed towards Process R&D. Finally, some variables commonly used in the relevant literature, such as industry concentration and demand, do not exhibit significant influence on R&D intensity once proper control is made for technological opportunity or/and firm-specific variables.

These results show that the most important determinants of R&D activity should be rather identified among the internally generated resources and not among the environmental – structural characteristics which tended to be overemphasized until recently.

Future research should be directed towards testing the impact of firm-specific resources on innovative output (which was not possible for the present study due to data restrictions), as well as for different countries and time periods.

References

1. Arrow, Kenneth J. (1962), "Economic welfare and the allocation of resources for invention", in (eds) R. R. Nelson, *The rate and direction of inventive activity*, Princeton, Princeton University Press.
2. Cohen, Wesley (1995), "Empirical studies of innovative activity", in (eds) P. Stoneman, *Handbook of the economics of innovation and technological change*, Oxford, Oxford University Press.
3. Cohen, Wesley M. and Levin, Richard, C. (1989), "Empirical studies of innovation and market structure", in (eds) R. Schmalensee and R. D. Willig, *Handbook of industrial organisation*, Amsterdam, Elsevier.
4. Symeonidis, George (1996), "Innovation, firm size and market structure: Schumpeterian hypotheses and some new themes", OECD Economics Dept. Working Paper No. 161.
5. David, Paul A., Hall, Bronwyn H. and Toole, Andrew A., (2000), "Is public R&D a complement or substitute for private R&D? A review of the econometric evidence", *Research Policy*, 29(4-5), pp. 497-529.
6. Del Canto, Jesús Galende and González, Isabel Suárez, (1999), "A resource-based analysis of the factors determining a firm's R&D activities", *Research Policy*, 28, pp. 891-905.
7. Galbraith, John K. (1985), *American Capitalism: The Concept of Countervailing Power*, revised edition, Boston, MA: Houghton Mifflin.
8. Jovanovich, Boyan (1982), "Selection and the evolution of industry", *Econometrica*, 50 (3), pp. 649-670.
9. Klette, Tor Jacob and Kortum, Samuel S. (2002), "Innovating firms and aggregate innovation", *CEPR Discusion Paper No. 3248*.
10. Nelson, Richard R. (1986), "Institutions supporting technical advance in industry", *American Economic Review Proceedings*, 76, pp. 186-189.
11. OECD, (2001), Science, Technology and Industry Scoreboard 2001, Towards a Knowledge-based Economy.
12. Pavitt, Keith (1984), "Patterns of Technical Change: Towards a Taxonomy and a Theory", *Research Policy*, 13(6), pp.343-73.
13. Peteraf, M. A., (1993), "The cornerstones of competitive advantage: a resource-based view", *Strategic Management Journal*, 14 (3), pp. 179-191.

14. Prahalad, C. K. and Hamel, G., (1990), "The core competence of the corporation", *Harvard Business Review*, 90 (3), pp. 79-91.

15. Scherer, F. and Ross, D. (1990), *Industrial Market Structure and Economic Performance*, Houghton Mifflin Company, Boston.

16. Schmookler, Jacob (1966), *Invention and Economic Growth*, Cambridge: Harvard U. Press.

17. Schumpeter, Joseph A. (1942), Capitalism, Socialism and Democracy, New York, NY: Harper and Row.

18. Wernerfelt, B., (1984), "A resource-based view of the firm", *Strategic management Journal*, 5, pp. 171-180.

Table 1: Comparisons (1996) between R&D and non-R&D performers with respect to firm size*

	Assets	**Sales**	**Employment**
R&D performer > Average non-R&D performer	130	124	129
R&D performer < Average non-R&D performer	13	15	20
Insignificant difference	68	72	62
Total	211	211	211

* t-tests: level of significance is 5%

Table 2: Comparisons (1996) between R&D and non-R&D performers with respect to profits*

	Net Profits/Sales	**Non-distributed Profits/Sales**
R&D performer > Average non-R&D performer	64	90
R&D performer < Average non-R&D performer	36	50
Insignificant difference	111	71
Total	**211**	**211**

* t-tests: level of significance is 5%

Table 3: Comparisons (1996) between R&D and non-R&D performers with respect to leverage and amortisation*

	Leverage	**Amortisation**
R&D performer > Average non-R&D performer	43	71
R&D performer < Average non-R&D performer	69	51
Insignificant difference	99	89
Total	**211**	**211**

* t-tests: level of significance is 5%

Table 4. Determinants of R&D Intensity

	All Firms (n=211) (a)	Firms in High technology industries (n=77) (b)	Firms in Medium-low technology industries (n=134) (c)	Small (n=71) (d)	Medium (n = 70) (e)	Large (n = 70) (f)
lnSales	-0.012***	-0.020	-0.012***	-0.038	-0.001	-0.002
	(3.167)	(1.642)	(2.956)	(1.270)	(0.192)	(0.072)
Herf	-0.006	0.007	0.009	-0.109	0.017	0.001
	(0.274)	(0.186)	(0.552)	(1.136)	(1.354)	(0.128)
lnIndSales	-0.002	0.001	0.005	-0.001	0.001	-0.001
	(0.405)	(0.006)	(1.230)	(0.079)	(0.216)	(0.037)
IndGrowth	-0.017	-0.044	0.027	-0.072	0.016	-0.003
	(0.880)	(1.281)	(1.291)	(0.805)	(0.793)	(0.379)
GovRD	0.018**	0.042	0.014**	0.043*	-0.003	-0.008***
	(2.159)	(1.355)	(2.090)	(1.926)	(0.607)	(2.981)
Amortisation	0.191***	0.405**	-0.041	0.218	-0.063	0.146
	(2.868)	(2.609)	(0.743)	(1.317)	(1.284)	(1.595)
SPersonnel	0.103***	0.165**	0.054**	0.165*	0.061***	0.003
	(2.780)	(2.214)	(2.392)	(1.970)	(3.440)	(0.486)
XI	0.007	0.066	-0.008	0.018	0.008	0.002
	(0.446)	(0.954)	(1.208)	(0.309)	(1.132)	(0.508)
NDP	0.002	-0.010	0.002*	-0.002	0.018	-0.004
	(1.172)	(0.324)	(1.875)	(0.661)	(1.463)	(0.676)
Leverage	-0.001	0.011	0.001	-0.001	-0.004	-0.001
	(1.006)	(0.620)	(1.401)	(0.114)	(1.180)	(0.994)
Age	-0.001	-0.001*	0.001	-0.001	-0.002**	-0.007
	(0.653)	(1.983)	(0.783)	(0.645)	(2.064)	(0.130)
Adj.R-squared	0.250	0.241	0.254	0.219	0.257	0.265

* Significant at the 10% level (two-tailed test), ** Significant at the 5% level (two-tailed

t ratios are in parentheses. Standard errors are White heteroskedasticity

Equations (a), (d), (e) and (f) include technology dummies (as defined in the text) which are always significant as a group at the 5% level.

Table 5. Determinants of Process R&D Intensity (Tobit estimation)

	All Firms (n=211) (a)	Firms in High and Medium-high technology industries (n=77) (b)	Firms in Medium-low and low technology industries (n=134) (c)	Small Firms (n=71) (d)	Medium Firms (n = 70) (e)	Large Firms (n = 70) (f)
lnSales	-0.002	-0.002	-0.002	-0.004	0.002	-0.001
	(1.425)	(1.351)	(1.241)	(0.738)	(0.389)	(0.552)
Herf	0.004	0.016*	-0.001	-0.021	0.018	0.004
	(0.590)	(1.889)	(0.146)	(0.943)	(1.361)	(1.455)
lnIndSales	-0.001	0.002	0.001	-0.001	0.002	0.001
	(0.285)	(0.149)	(0.556)	(0.335)	(0.722)	(0.507)
IndGrowth	0.001	-0.014	0.039***	-0.019	0.033*	-0.002
	(0.054)	(1.534)	(2.992)	(1.039)	(1.882)	(0.536)
GovRD	0.008***	0.009**	0.008**	0.023***	0.005	-0.003**
	(2.736)	(1.983)	(2.055)	(3.151)	(1.030)	(2.228)
Amortisation	0.007*	0.006	0.008	0.003	-0.019	-0.006
	(1.923)	(1.321)	(1.603)	(0.520)	(0.342)	(0.266)
SPersonnel	0.009	0.020**	0.004	0.005	0.029**	-0.001
	(1.351)	(2.447)	(0.441)	(0.328)	(2.092)	(0.552)
XI	-0.002	0.012	-0.007	-0.005	0.004	0.001
	(0.404)	(1.508)	(1.228)	(0.409)	(0.511)	(0.663)
NDP	0.001	-0.001	-0.008	-0.001	0.023	-0.004
	(0.071)	(0.012)	(0.040)	(0.428)	(1.407)	(1.437)
Leverage	0.002	0.001	0.003	-0.001	-0.008***	0.006
	(0.161)	(0.694)	(0.245)	(0.268)	(2.812)	(0.192)
Age	-0.002	-0.001*	0.008	0.006	-0.005	-0.008
	(0.300)	(1.834)	(1.019)	(0.322)	(0.433)	(0.384)
Log likelihood	404.7	143.0	270.9	107.2	129.8	255.9

* Significant at the 10% level (two-tailed test), ** Significant at the 5% level (two-tailed test), *** Significant at the 1% level (two-tailed test).
t ratios are in parentheses.
Equations (a), (d), (e) and (f) include technology dummies (as defined in the text) which are always significant as a group at the 5% level.

Table 6. Determinants of Product R&D Intensity (Tobit estimations)

	All Firms (n=211) (a)	Firms in High and Medium-high technology industries (n=77) (b)	Firms in Medium-low and low technology industries (n=134) (c)	Small Firms (n=71) (d)	Medium Firms (n = 70) (e)	Large Firms (n = 70) (f)
lnSales	-0.008**	-0.013	-0.009***	-0.026	0.002	-0.001
	(2.563)	(1.391)	(3.182)	(1.209)	(0.397)	(0.353)
Herf	-0.005	-0.007	0.138	-0.052	-0.002	0.004
	(0.266)	(0.154	(0.814)	(0.598)	(0.183)	(0.543)
lnIndSales	-0.002	-0.004	0.006**	-0.002	-0.002	0.001
	(0.425)	(0.421)	(1.978)	(0.132)	(0.913)	(0.600)
IndGrowth	0.003	-0.027	0.032	-0.025	0.012	-0.007
	(0.156)	(0.573)	(1.415)	(0.366)	(0.798)	(0.862)
GovRD	0.007	0.036	0.004	0.029	-0.005	-0.005*
	(0.956)	(1.412)	(0.554)	(0.941)	(1.213)	(1.700)
Amortisation	0.026***	0.431**	0.018**	0.293	0.020	0.149***
	(2.821)	(2.561)	(2.084)	(1.606)	(0.428)	(3.004)
SPersonnel	0.083**	0.152***	0.034**	0.154***	0.038***	0.004
	(2.452)	(3.513)	(2.246)	(2.622)	(3.264)	(0.619)
XI	-0.004	0.055	-0.014	0.023	-0.004	-0.002
	(0.307)	(1.225)	(1.470)	(0.439)	(0.583)	(0.445)
NDP	0.001	-0.010	0.001	-0.003	0.023*	0.001
	(0.525)	(0.178)	(0.300)	(0.240)	(1.758)	(0.231)
Leverage	-0.001	0.011	-0.001	0.001	-0.002	-0.005
	(1.062)	(0.950)	(0.059)	(0.155)	(0.088)	(0.725)
Age	-0.001	-0.001	0.001	-0.001	-0.003	-0.002
	(0.736)	(1.116)	(1.470)	(0.896)	(0.316	(0.470)
Log likelihood	231.4	72.4	217.5	49.6	169.5	196.9

* Significant at the 10% level (two-tailed test), ** Significant at the 5% level (two-tailed test), *** Significant at the 1% level (two-tailed test).
t ratios are in parentheses.
Equations (a), (d), (e) and (f) include technology dummies (as defined in the text) which are always significant as a group at the 5% level.

Table 7: Comparisons (1996, 1999) between R&D and non-R&D performers with respect to firm size*

	Sales 1996	Sales 1999	Employment 1996	Employment 1999
R&D performer > Average non-R&D performer	115	120	121	131
R&D performer < Average non-R&D performer	13	14	18	15
Insignificant difference	70	64	59	52
Total	**198**	**198**	**198**	**198**

* t-tests: level of significance is 5%

Table 8: Comparisons (1996, 1999) between R&D and non-R&D performers with respect to profits*

	Profits/Sales 1996	Profits/Sales 1999	Non-distributed Profits/Sales 1996	Non-distributed Profits/Sales 1999
R&D performer > Average non-R&D performer	61	85	83	89
R&D performer < Average non-R&D performer	35	36	49	47
Insignificant difference	102	77	66	62
Total	**198**	**198**	**198**	**198**

* t-tests: level of significance is 5%

Table 9: Comparisons (1996, 1999) between R&D and non-R&D performers with respect to leverage and amortisation*

	Leverage 1996	Leverage 1999	Amortisation 1996	Amortisation 1999
R&D performer > Average non-R&D performer	41	27	69	96
R&D performer < Average non-R&D performer	61	63	48	34
Insignificant difference	96	108	81	68
Total	**198**	**198**	**198**	**198**

* t-tests: level of significance is 5%